Extracting and Unfolding a Stratigraphic Unit to Update Property Population

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SUMMARY :
With the wide usage of geo-modelling tools, users could have the need to enhance their previous geostatiscal population without rebuilding an entire stratigraphic model
In this paper we explain how we can extract non explicit information from a stratigraphic model (reference iso-chronological surfaces, faults used to constraint the model), and then, use this information to realise 3D flattening on iso-chronological surfaces prior to geostatiscal population.

Three methods were presented here: traditional by topological correspondence, vertical shear and an original isometric unfolding process based on the minimization of the elastic tensor deformation. These methods could be applied for every type of deposit: Horizontal, Parallel to Top, parallel to Bottom, Proportional.

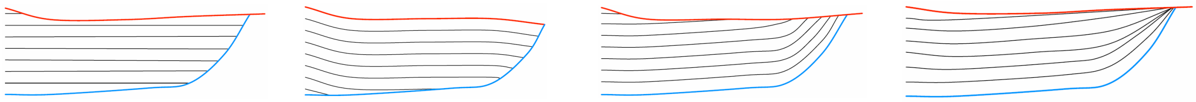
Then, we compare the application of these methods on several case studies and develop the advantages to reengineer a stratigraphic model and repopulate it after flattening.

Even if the "traditional" and vertical shear methods could be applied on certain situations, following multiple test bed as the ones presented in this paper, we are thinking that the isometric unfolding presented here is much reliable. As a consequence, we will exploit more and more this isometric unfolding method in the next future and process each lithostratigraphic unit independently than the others.

Introduction

With the wide usage of geo-modelling tools, users could have the need to enhance their previous geostatiscal population without rebuilding an entire stratigraphic model. This may be useful if a new well delivers updated data, if the user would like to apply new geostatiscal population methods or would like to constraint the property population after some non consistent fluid flow simulation tests. For this opportunity, they often need to extract with a chirurgical precision a single lithostratigraphic unit and "repopulate" it with other accurate methods.

In this paper we explain how we can extract non explicit information from a stratigraphic model (reference iso-chronological surfaces, faults used to constraint the model), and then, use this information to realise 3D flattening on iso-chronological surfaces prior to geostatiscal population. With our methods this 3D Flattening can be optimised for every type of deposit: Horizontal, Parallel to Top, parallel to Bottom, Proportional (Figure 1).



(a) (b) (c) (d)

<u>Figure 1:</u> deposit domain (a) horizontal (b) parallel to top (c) parallel to bottom (d) proportional

In every of these use cases, the objective to apply our methods is to avoid lateral deformation due to the influence of the setting up of complex fault network as presented in [2] and [3]. Then, the original distance between geological bodies will be restored as it was historically and the computed geostatistical parameters (experimental lateral and vertical variograms) will be more consistent.

Depending on the use case we can apply 1/ a traditional topological relationship between the litho stratigraphic grid and a flat regular grid designed to handle geostatistical computation, 2/ a simple vertical shear, 3/ a single isometric unfolding or 4/ a double isometric unfolding method. Then, using any of these restoration policies, we can replace the well bore trajectories and the measurements along this trajectory in the historical depositional situation.

The following step is common to all use cases, a regular orthogonal 3D grid embedding these measurements in the deposit space is defined. This grid represents a regular media on which complex fault network effects are erased, and is used to apply geostatistical population.

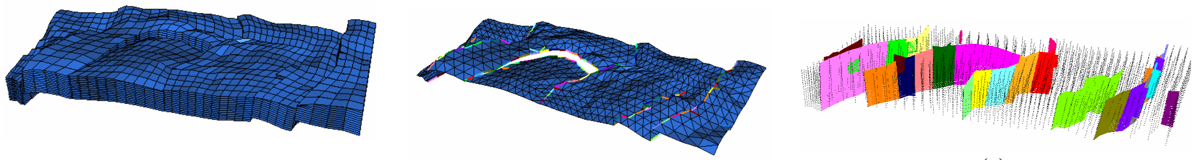
In this paper we compare the application of these diverse methods on several case studies and develop the advantages to reengineer a stratigraphic model and repopulate it after flattening. We do not cover the total reconstruction of an assemblage of several lithostratigraphic grids in a [U,V,T] parametric grid as it is proposed by the SKUA product from Paradigm (http://www.pdgm.com/products/skua.aspx), because we are just extracting and filling one existing lithostratigraphic unit without rebuilding the whole model.

Preliminary extraction of non explicit information (iso-chronostratigraphic surface, Horizon/Faults contacts):

As a first step, we will show how we can re-engineer a "coordinate line" designed stratigraphic grid to extract significant stratigraphic surfaces and embedded fault networks.

Our starting point is a coordinate line (or pillar organised) 3D grid with a regular I, J, K organisation. A first exploration of this 3D grid allows to define which K = *Cte* limit could be chosen as an iso-chrono-stratigraphic surface.

A deeper exploration allows determining "horizon/faults contacts", computing the link between upper and lower margin of a fault on its horizon/fault contact for each discontinuity and informing the topological framework on the entire 3D stratigraphic grid. This step is not the simplest part of the process and a lot of heuristics have to be considered to obtain a 100 % consistent framework. Figure 2 present horizons and faults and their links extracted from a faulted 3D stratigraphic model.



(a) (b) (c)

Figure 2: *extraction of non explicit information (a) faulted stratigraphic 3D grid (b) one extracted horizon and corresponding horizon/faults contacts (c) set of extracted fault surfaces.*

Unfolding process methods

1/Traditional method:

This method is commonly used by most of geo-modelling tools. It consists in building a flat regular grid in the deposit domain. In this case the stratigraphic grid deposit domain will be an orthogonal grid with dimensions along I, J, and K calculated from the original Lithostratigraphic unit dimension (an average of the height, length and depth value of the cells is often used). The value of the properties measured in a [i, j, k] cell of the original lithostratigraphic grid is transported in the same [i, j, k] cell of the regular stratigraphic grid defined in the deposit domain.

2/ 3D Flattening using a simple vertical shear

This method, which is very fast, is very well fitted if the deposition mode is horizontal but it could be used also for the other deposition mode if the structure is not too complex. We must chose one K= *Cte* limit as the reference iso-chronological surface. Far from the faulted area, we compute the vertical distance of each node (each I, J, K corner) of the original stratigraphic grid, to the iso-chronological surface.

By this way we can build a partial flattened stratigraphic grid which is an image of 80 % to 95 % of the original stratigraphic grid as it was historically located during the deposition period in the depositional domain. Then, along the faults, considering that very often the thickness of the layer doesn't vary too much, we can extend smoothly the partial flattened stratigraphic grid to the faulted area and complete it at 100%. Two options are provided to the user: impose or not the adjacency along the faults in the deposit space.

3/ 3D Flattening using an isometric unfolding

This method is very well sweated if the deposition mode is parallel to an iso-chronological surface. We must choose also one K= *Cte* limit as the reference iso-chronological surface. It is here mandatory to start from a very consistent structural model on which horizon/fault contacts are explicitly known. The preliminary extraction presented before guarantees the respect of this constraint.

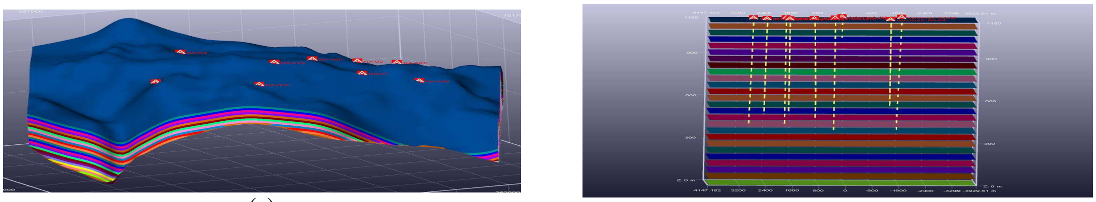
The mathematical concepts of the flattening algorithm are detailed in a paper proposed to the next ECMOR conference. This algorithm is based on an isometric unfolding process. The unfold surface is computed by deforming a 3D fold surface. The criterion chosen is the minimization of the elastic tensor deformation.

From an unfolded reference surface (RS) chosen by user, all horizons included between base and roof are "redressed" [1]. For this, the deformation apply on each reference surface point is firstly compute and secondly is apply along the corresponded coordinate-line in the stratigraphic grid.

Computing the well bore trajectory in the depositional domain

Both presented process (Vertical shear and Isometric) gave a complete correspondence exists between all the cells of the two grids.

Starting from the (x_i, y_i, z_i) trajectory of the well bore, we can calculate from each well measurement (mw_x, mw_y, mw_z) the local mu, mv, mw coordinates of the well measurements in each (crossed) cell of the original stratigraphical grid, then replace this well measurement in each corresponding cell of the flattened stratigraphic grid and obtain the dw_x, dw_y, dw_z coordinates of this well measurement in the depositional domain. This property value is now “located” as it was in the 3D space during the deposition period (Figure 3). This property and its location can now be used to calculate geostatistical population in this depositional domain.



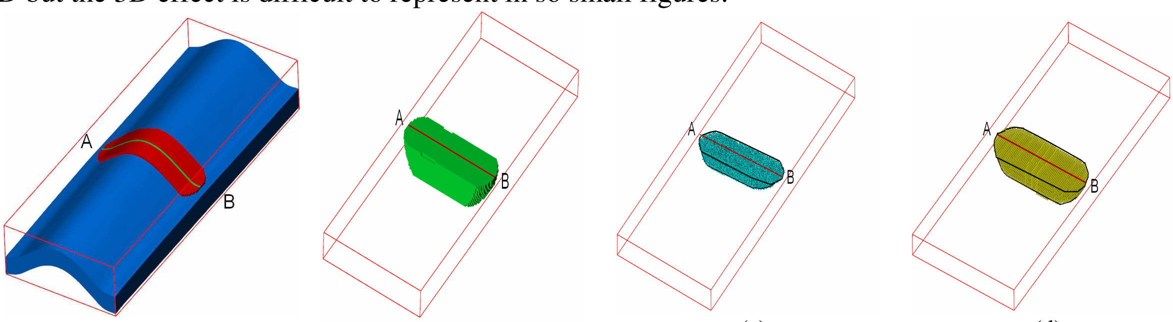
(a) (b)

Figure 3: *Properties management (a) stratigraphic 3D model with wells properties (b) properties location in depositional domain.*

Examples discussions and comparisons

In this section we are going to compare what is the effect on the spatial features of the first three methods presented on two examples: a “bended” and a “faulted” litho stratigraphic grid. For these two use cases a number of connected cells was embedded into these grids to represent a 3D sedimentary body embedded into a Lithostratigraphic unit. The objective of this exercise is to determine which method will deliver the best information to compute experimental variograms for geostatistics, so which method can keep the original lateral and vertical extension of this sedimentary body.

1/ For the “bended” stratigraphic unit (Figure 4) on which have a measured length of 3800 m in the maximal lateral extension of the sedimentary body, we obtain 3335 m for the “traditional method”, 3327 m for the Vertical Shear method, 3776 m for the isometric method. For maximal vertical extension we obtain the following values: 66.8 m; 66.8 m; 68.2 and 67.0 m. It is not very “flashy” in 2D but the 3D effect is difficult to represent in so small figures.



(a) (b) (c) (d)

Figure 4: *Distance measured in resulting grid between two points A and B: (a) lithostratigraphic grid; (b) flattened by the traditional method; (c) by the vertical shear, (d) by the isometric.*

2/ For the "faulted" stratigraphic unit (Figure 5), we will consider the shape of the flattened sedimentary body and verify that the "fault effect" could be erased if we do not use the Vertical shear method as well as the distance are conserved. In this example, coming from a realistic data set, the cells defined in the original stratigraphic grid are transported in the historical depositional refined grid as pseudo well bore measurements, ready to be used by geostatistical methods.

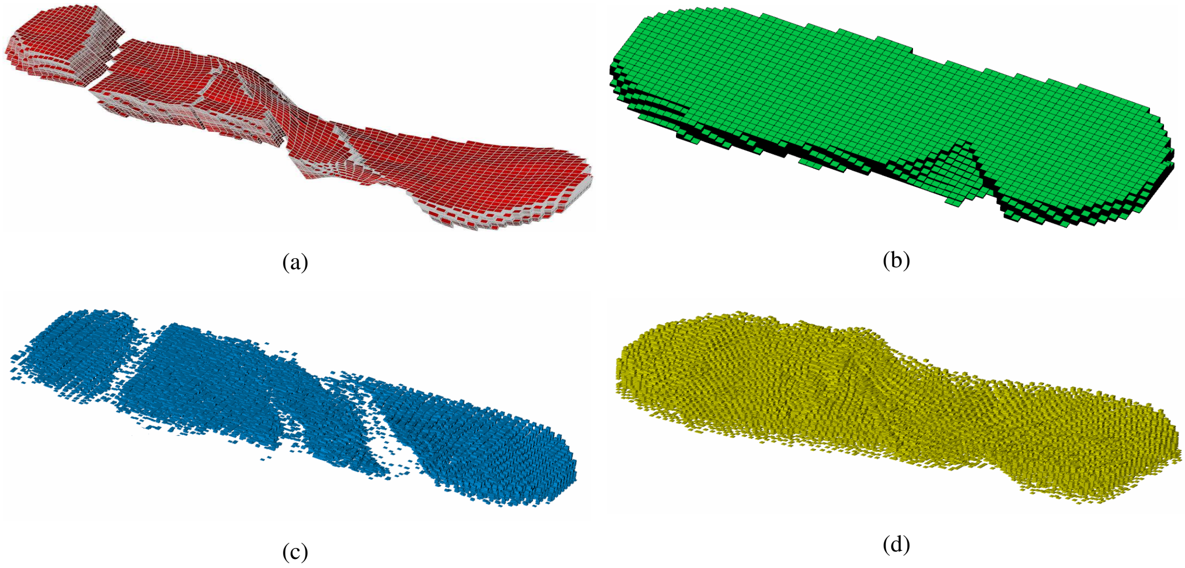


Figure 5: *Processing on a grid including fault:(a) original lithostratigraphic grid; (b) flattened by the traditional method; (c) by the vertical shear, (d) by the isometric.*

Conclusions and Future works

After explaining how we extract geometry and topology features from "already defined" stratigraphic grids embedded into a wide reservoir grid, we presented here several unfolding methods used to transfer all measurements along well trajectories in a flat depositional domain. By using these methods on an updating loop, we will be able to start from an existing model already populated, introduce new information (measurements along well bores or new seismic attribute constraints) and decide to change our mind on the deposition mode before computing an up to date geostatistical estimation. It will be also possible to introduce this new step in the reservoir characterisation process and build up optimisation loop with.

Even if the "traditional" and vertical shear methods could be applied on certain situation, following multiple test bed as the ones presented in this paper, we are thinking that the isometric unfolding presented here is much reliable. As a consequence, we will exploit this method in the next future. This method will be helpful to complete our geo-modelling process with more functions using geometrical correspondence like direct upscaling from deposit location to reservoir grid and/or grid refinement assisted by property contrast and structural constraints. Our policy will be to process each lithostratigraphic unit independently than the others.

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